Flow Measurement Calibration and Measurement

Flow measurement for agricultural irrigation delivery can be accomplished with four general approaches. These categories are generalized below.

I. Standard pipeline measurement
II. Standard open channel measurement
III. Non-standard open channel measurement
IV. Other measurements

Category I

The first category includes devices with totalizers that measure volume. These devices might measure velocity, flow rate or volume directly. All of these devices will provide a direct volumetric reading. The devices in Category I include:

- Propeller meters
- Venturi meters with flow recorders
- Magnetic meters
- Acoustic meters

These have a high level of accuracy with proper installation and periodic maintenance and calibration.

Category II

The second category involves devices used for open channels. The second category includes:

1. Standard flow measurement devices that measure flow rate and also require accurate measurements (hourly or more frequently) of water level **or,**
2. The same standard devices combined with excellent canal water level control using positive means such as flap gates, long-crested weirs, or properly designed PLC-controlled water level control gates.

In all cases, the total delivery time must be accurately known to give a final volumetric answer within +/- 6%. The following devices, if properly designed, installed, calibrated, and maintained, can qualify as "standard" flow measurement devices:

1. Replogle and Parshall flumes
2. Rectangular or trapezoidal (Cipolletti) or V-Notch weirs
3. Canal meter gates (canal meter gates only qualify if both upstream and downstream water levels can be measured at the proscribed locations)
4. Various orifice devices

Category III

The third category includes non-standard, individually calibrated flow measurement devices. These are often special measurement devices developed by an irrigation project. Typically, there are no published standard dimensions or flow tables for such devices. Requirements for acceptability would include:

- Consistent dimensions and installations
- Accurate determination of delivery time
- Local calibration and a verification of accuracy, based on a representative sample number of devices measured over time (see guidelines later in this document)
- A proposed schedule for maintenance and calibration

Devices in this category also require:

- Accurate measurements of water level (taken hourly or more frequently), or
- Excellent water level control using positive means such as flap gates, long-crested weirs, or properly designed PLC-controlled water level control gates, along with delivery time to determine volumes, or
- Adequate delivery pools for accurate deliveries (demonstrated with a verification procedure)

This category also includes calibrated pumps in cases where the suction-side water level fluctuation is small when compared to the total lift (+/- 5 percent) and the discharge pressure does not change with time.

Category IV

A fourth category includes using rough estimates of flow rate or volume, such as flow-rate estimates at check structures or the sum of siphon tubes (or other methods of measurement not specified here). These approaches are NOT acceptable since they do not provide a documented reasonable degree of accuracy.

Table 1 shows a general outline of the devices and the expected accuracy of the devices. This table shows that many of the devices used for irrigation flow measurement can have a good accuracy if installed correctly. The table also provides the references for the potential maximum accuracy of irrigation measurement devices.

Table 1. Device flow rate accuracy values (to aid with developing CWD §10608.48(i) regulations)
[Note: The information entered below will be posted on a public website]

Device Category	Example Types	USBR - Lab (Flow Rate)	ILRI20 - Lab (Flow Rate)	Reference & Notes (See footnotes for links to references)	ITRC - Field (Flow rate)	Reference & Notes
		Potential Flow Rate Accuracy Assuming Proper Installation and Maintenance				
Pipelines		(%)			(%)	
Propeller meters		2%	5%	USBR - Section 14-4, Pg. 14-12. ILRI20 -Table 3.1, Section 9.7. Must have at least 8-10 diameters upstream and 4 diameters downstream. Meters must be maintained and checked for accuracy at least every 5 years. See the link below from the USBR-MPR for the maintenance and protocol requirements. ITRC note: It is possible to place customized flow conditioning upstream that minimizes errors due to rotating flow and non-symmetric flow. Propeller meters are sensitive to trash accumulation. Some models have serious bearing problems with sand/silt.	5%	Estimated by ITRC
Magnetic meters						
	Full bore	1%	---	USBR - Section 14-6, Pg. 14-18. Recommended to have at least 2 diameters upstream and 1 diameter downstream. Major differences between manufacturers. Some have built-in flow conditioning. One of the most accurate flow measurement devices.	3%	Estimated by ITRC
	Insert	---	---	ITRC notes: Insert meters must have an excellent straight section of pipe upstream and downstream; accuracy is limited. Not recommended for turnouts.	?	
Acoustic Meters						
	Transit-Time	2%	---	USBR - Section 11-1, Pg. 11-3. ITRC notes: Results with "dry" transducers can be variable.	5%	Estimated by ITRC
	Doppler	2%	---	USBR - Section 11-8, Pg. 11-15. Highly dependent on the canal section to obtain good accuracy. ITRC note: There are huge differences in quality among the manufacturers. Some are excellent; some are very undependable and have been abandoned by irrigation districts.	5%	Estimated by ITRC
Differential head meters						
	Venturi	1%	---	USBR - Section 14-3	5%	Estimated by ITRC
	Orifice	1%	---	USBR - Section 14-3. ITRC notes: Few orifice meters used in agricultural irrigation turnouts because of narrow range of flow rate accuracy, head loss, and difficulty in measuring the difference in head. Not recommended for turnouts	?	
Electricity KWH meter				ITRC notes: Not recommended. Some users will use a flow rate from a pump test and extrapolate a value for AF/KWH. This approach is very inaccurate.	50+%	Estimated by ITRC
Open Channel						
Metergates		2.5%	6%	USBR - Section 9-14, Pg. 9-23. ILRI20 - Table 3.1, Section 8.6. Main issue is that the standard conditions used to create the flow tables must be met. In addition, the following specific conditions must be met: "Zero" height is when the gate starts to leak and must be verified for each gate. Always pull up on shaft to take a reading. Keep the bottom of the gate entrance clean/clear to maintaing a constant flow characteristic. A water level in the downstream pool is not same as a properly set stilling well 12-in behind the gate. Eddies or vortexing at the gate entrance will generally cause an overestimation of the flow rate. The accuracy is poor if the gate is more than 70% open. If installed according to a manufacturer's specifications, with a well-calibrated chart provided by the	5%	Estimated by ITRC

Calibrated slide or sluice gates		2%	---	Estimated by ITRC. ITRC notes: Numerous conditions for calibration must be met, as with metergates. Standard textbook calibrations are rarely satisfactory. Calibration must correspond to the specific dimensions and inlet/outlet conditions. Must constantly be in either free flow or submerged conditions.	5%	Estimated by ITRC
Constant Head Orifice		3%	7%	USBR - Section 9-11-b, Pg. 9-14. ILRI20 - Table 3.1, Section 8.3. The poor accuracy reported by ILRI20 was based on information from the 1980s, and because of inherent dislike of CHOs that were inappropriately used in foreign projects. The 2nd gate simply maintains a submerged condition on the first gate. Same accuracy as calibrated slide or sluice gates.	5%	Estimated by ITRC
Weirs						
	Rectangular	1%	1%	USBR - Section 7-17. ILRI20 - Table 3.1, Section 5.1. ITRC notes: In general, there is insufficient head in California for widespread usage of these.	5%	Estimated by ITRC
	V-notch	1%	1%	USBR - Section 7-17; Section 7-11, Pg. 7-20. ILRI20 - Table 3.1, Section 5.2.ITRC notes: In general, there is insufficient head in California for widespread usage of these.	5%	Estimated by ITRC
	Cipoletti	1%	5%	USBR - Section 7-17. ILRI20 - Table 3.1, Section 5.3. ITRC notes: In general, there is insufficient head in California for widespread usage of these.	5%	Estimated by ITRC
Acoustic Meters						
	Transit Time	2%	---	USBR - Section 11-1, Pg. 11-3. Must be maintained and field verified weekly. ITRC note: Generally not applicable to turnouts.	5%	Estimated by ITRC
	Doppler	2%	---	USBR - Section 11-8, Pg. 11-15. Highly dependent on the canal section to obtain good accuracy. ITRC note: There are huge differences in quality among the manufacturers. Some are excellent; some are very undependable and have been abandoned by irrigation districts.	5%	Estimated by ITRC
	Doppler with control section	---	---	New structure design by ITRC. Uses a stucture to straighten the stream lines in combination with an uplooking Doppler. http://cedb.asce.org/cgi/WWWdisplay.cgi?267867. With a high quality of Doppler, this can be an excellent technique.	3%	Estimated by ITRC
Flumes						
	Parshall	2%	3%	USBR - Section 8.10, Pg. 8-21. Not recommended by USBR for new installations (Pg. 8-40). ILRI20 - Table 3.1, Section 7.4.	5%	Estimated by ITRC
	Replogle Flumes, aka "Ramp flume", "broadcrested weir"	2%	3%	USBR - Section 8.8.a, Pg. 8-21. ILRI20 - Table 3.1, Section 7.1. ITRC notes: These can be excellent if designed and maintained properly. Very sensitive to incorrect design, not using as-built dimension in rating tables, incorrect positioning of "zero" on staff gauge, and poor downstream conditions that cause submergence at high or low flows. Nevertheless, can be excellent in the correct situation.	3%	Estimated by ITRC
	Cutthroat flumes	-	-	ITRC note: Not recommended. Although they received considerable attention in Colorado, subsequent work indicates they have poor accuracy.		
Radial gate		---	5%	USBR - Section 9.13. Reported as complex to evaluate. ILRI20 - Table 3.1, Section 8.4. Rarely if ever used for turnouts.	5%	Estimated by ITRC

USBR Reference (9mB):

http://www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/wmm.html
Water Measurement Manual, A Water Resources Technical Publication\
US Department of the Interior, Bureau of Reclamation, Third Edition - 2001

ILRI 20 Reference (18.6 mB):

http://content.alterra.wur.nl/Internet/webdocs/ilri-publicaties/publicaties/Pub20/pub20.pdf
Discharge Measurement Structures (third edition), 1976/1989.
Note: Most of the accuracy values are from Table 3.1 - Column 14

USBR-MPR Maintenance and Protocol Requirements for Flow Rate Measurement:

http://www.usbr.gov/mp/watershare/documents/Water_mgmt/Planner/2008%20%289%29%20Calibration%20and%20Measurement.pdf

Calibration and Measurement
Category I - Pipeline

There are four types of meters that can be used for velocity, flow rate, and volume measurements in pipelines. These devices, when placed at the correct location with a known area, can be very accurate with proper installation and periodic maintenance and calibration.

1. Propeller – Flow Meters
2. Venturi Meters
3. Magnetic Meters
4. Acoustic Meters

Table 2. Pipeline meter details

Meters	Installation	Maintenance	Calibration
Propeller Flow Meters	The inside diameter of the pipe (see **Figure 2**) must be known and supplied to the manufacturer. The meter must be centered in the pipelines in order to be accurate. Meters should be operated at greater than 1 foot/second.	Remove trash before it gets to the meter or frequently clean the propellers. Also, sand and normal wear can cause the propeller to not spin freely. The problem may show up as a more erratic needle movement.	Calibration is typically done by sending the unit back to the manufacturer on a regular maintenance cycle (every 2-5 years depending on experience). Field checks of meters can be done using a portable acoustic meter (transit time type).
Venturi Meters	Manufacturers of the Venturi meters should be requested to furnish the rating tables for the unit purchased. These meters are susceptible to turbulence.	The tubes used to measure the pressure can easily become plugged so they must be checked periodically.	Field calibration can be done using an insert pitot tube or a portable acoustic meter (transit time type).
Magnetic Meters	Spool type magnetic meters can be very accurate even with turbulence in the pipeline. A spool meter is one that comes with a factory section of pipeline. These can be more accurate since the inside diameter is controlled by the manufacturer. Insert magnetic meters should follow propeller meter installation guidelines.	Low maintenance on spool magnetic meters. Insert meter sensors must be periodically cleaned.	Field checks of meters can be done using a portable acoustic meter (transit time type).
Acoustic Meters	Acoustic meters can be used in both pipelines and channels. Acoustic meters should follow propeller meter installation guidelines.	Transducers (see **Figure 4**) must be periodically cleaned. It is important to avoid multipath interference and signal bending from solar heating.	Normally, these devices are not field calibrated.

Figure 1. Example of propeller meter measurement device

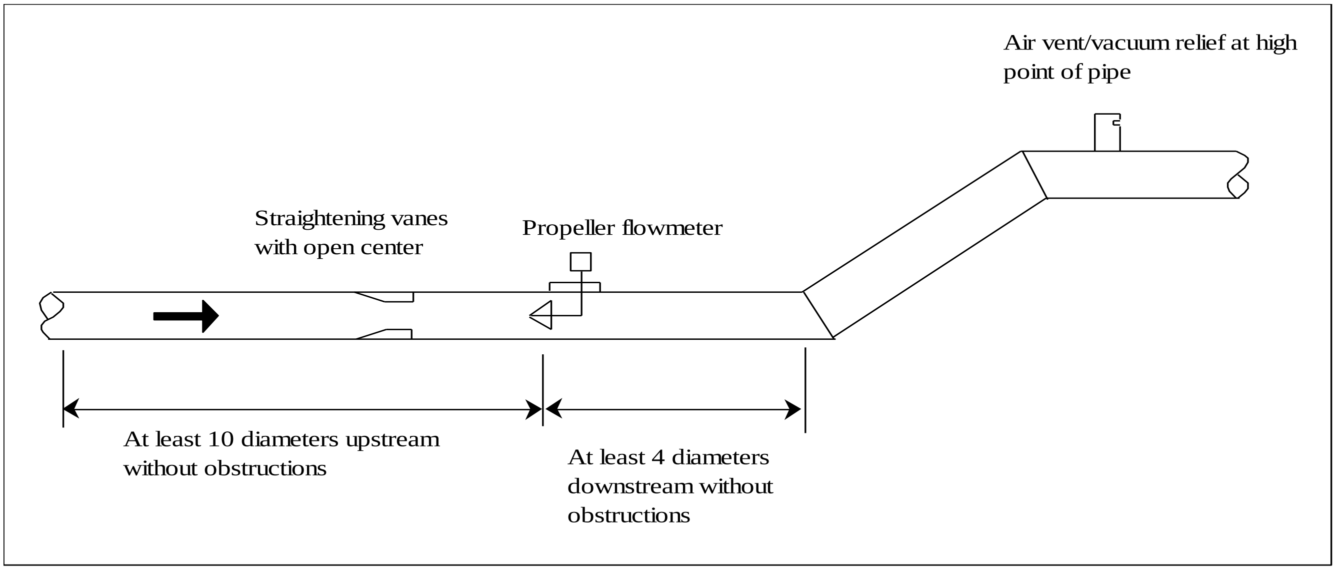


Figure 2. Inside Diameter (ID) of a pipe

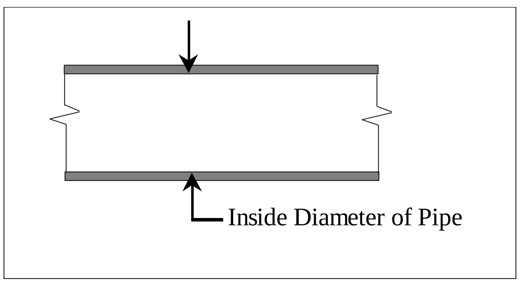
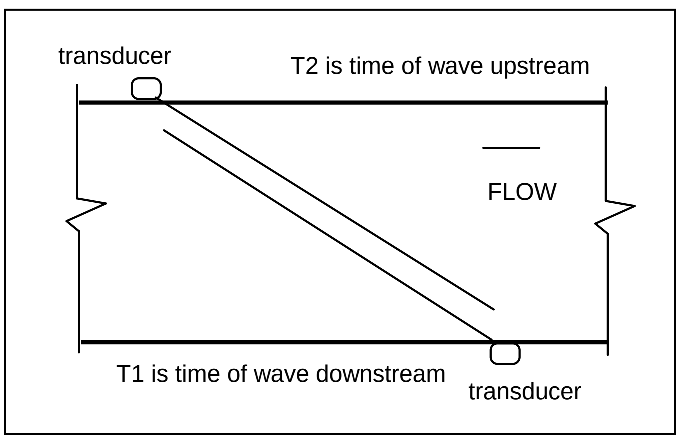


Figure 3. Acoustic Meter (Transit time style in pipeline)



Calibration and Measurement
Category II – Standard Open Channel

The second category includes standard flow measurement devices that measure flow rate and also require accurate measurements of delivery time to determine volumes:

1. Replogle and Parshall Flumes
2. Rectangular, Trapezoidal (Cipolletti), and V-Notch Weirs
3. Canal Meter Gates
4. Acoustic Meters

These devices require proper installation, regular recording of flow rates and delivery times, adjustments for approach velocity (in some cases such as the weirs), regular maintenance and calibration for good accuracy.

Table 3. Standard open channel device details

Flumes, Weirs and Gates	**Installation**	**Maintenance**	**Calibration**
Replogle and Parshall Flumes	It is essential that the entrance of the control section of the flume be level in the direction of the flow. Water must be moving “straight” toward the flume. The flume should be located about 10 times the average channel width downstream of checks, gates, or bends in the channel. Staff gages must be zero stage referenced. Staff gauges set too high will underestimate the actual flow rate.	It is important to keep the stilling wells (see **Figure 4**) from being plugged or partially plugged. The surfaces of the flume must be kept relatively clear of moss and sediment buildup. Limits of submergence should be checked at high and low-flow rates.	Can be installed with an accuracy of +/- 5 percent. The rating curve used for the flume can be field-verified using a current meter.
Rectangular and Trapezoidal Weirs (Cipolletti)	It is important that the weir crest be horizontal and level and for the sides of the rectangular weir to be vertical. The water must be moving straight into the weir, and the face of the weir must be vertical.	It is important to keep the stilling wells from being plugged or partially plugged. Flow into and out of the weir should be as smooth as possible. Sediment accumulation below the weir crest should be removed.	Rating tables must be adjusted to account for the **velocity of approach** for calibration. Rating tables must be checked for the correct weir (i.e., contracted weir vs. suppressed weir). Rating tables must be adjusted for submergence or slanted conditions.
V-Notch Weir	It is important to determine which size of notch (how many degrees) is being used so that the correct flow-rate table can be used. It is also important to determine if there are any errors in the construction of the notch. The water must be moving straight into the weir, and the face of the weir must be vertical.	Same as the rectangular and trapezoidal weirs above.	Same as the rectangular and trapezoidal weirs above.

Flumes, Weirs and Gates	**Installation**	**Maintenance**	**Calibration**
Canal Meter Gates	1. "Zero" height of the stem is when the flow starts to leak through the gate (see **Figure 5**). 2. Always pull up on shaft (via the turning wheel) before taking measurement. 3. Keep the bottom of the gate entrance clean. 4. A change in pipe material several diameters downstream of the gate will not affect the accuracy. 5. A water level in the downstream pool is not the same as a water level measured in a whistle pipe (see **Figure 6**). 6. Eddies at the gate entrance will generally cause an overestimation of the flow rate. 7. The accuracy is poor if the gate is more than 70 percent open.	Flow toward and into the structure should be as smooth as possible. Obstructions should be removed to improve the entrance conditions. Remove accumulations of sediment, because they may reduce the actual area of orifice. Debris, such as weeds, should also be removed.	Manufacturer's specifications must be followed precisely in order to obtain accurate flow rate measurements.
Acoustic Meters	Acoustic meters can be used in both pipelines and channels. Acoustic meters in canals are generally the Doppler style meters.	Transducers must be periodically cleaned. The units need to be free of moss/algae to operate.	For calibration by current-meter measurement, it is essential to place the device in a cross section that will not change significantly. If the transducers are placed out in the channel, the triangular side areas not measured must be accounted for in the calibration.

Figure 4. Stilling well used for open channel flow

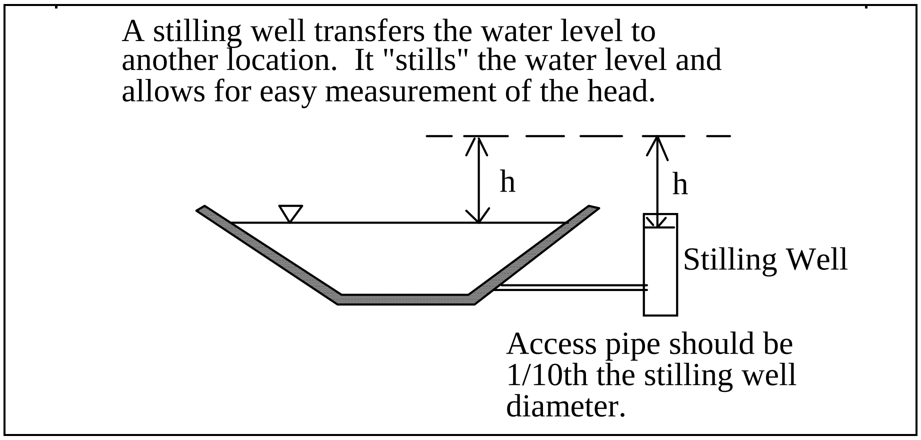


Figure 5. "Zero" reference for a meter gate

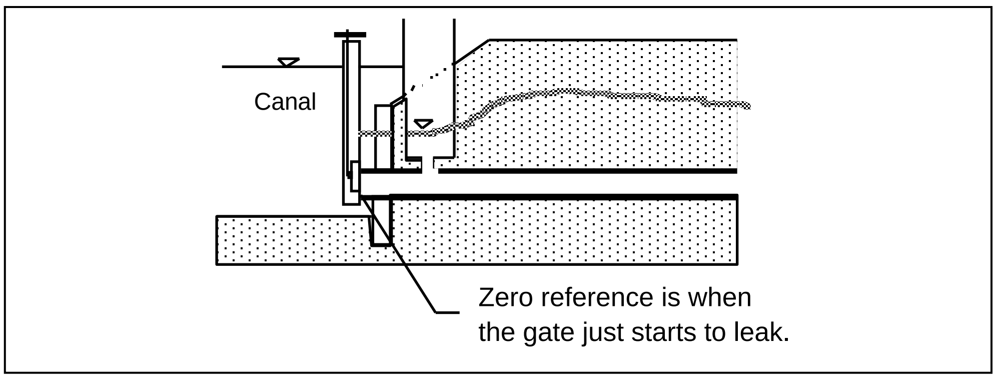
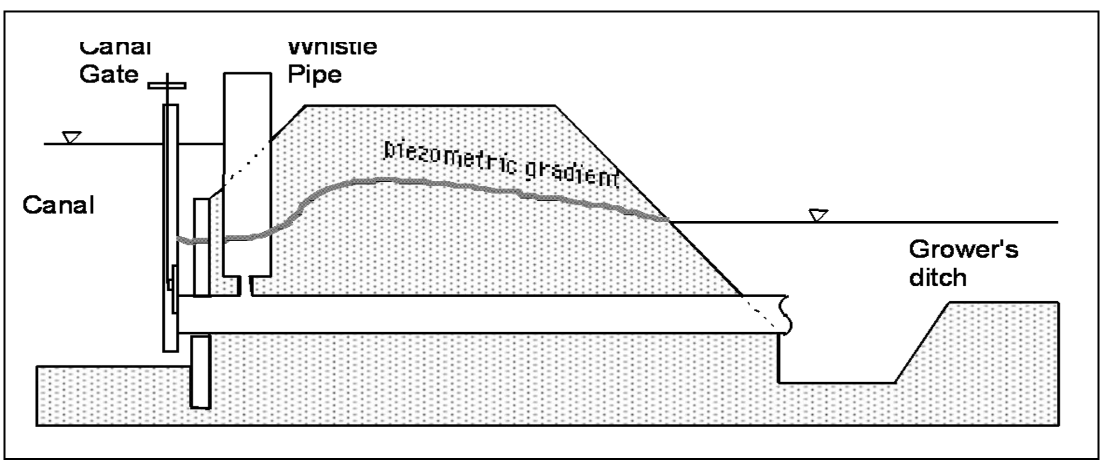


Figure 6. Cross section of a meter gate showing the water pressure through the pipe



Calibration and Measurement
Category III – Non-Standard Open Channel

The third category includes non-standard, calibrated flow measurement devices. This category includes special measurement devices developed by a district. Typically, there are no published standard dimensions or flow tables for such devices. Acceptability for devices in this category would require: consistent dimensions and installations; accurate determination of delivery time; local calibration and a verification of accuracy, based on a representative sample number of devices measured over time; and a proposed schedule for maintenance and calibration.

The following steps can be used to calibrate a non-standard structure:

1. Use a current meter to calibrate the non-standard structures. The individuals who will perform the current metering need to demonstrate proficiency in the required skills to perform the measurements. They need to follow manufacturers' guidelines for the in-situ field measurements.

2. The individuals making current meter measurements will need to use an established site such as a calibrated Replogle flume to verify their proficiency in making good current meter readings.

3. Non-standard structures have certain requirements that must be met in order to be calibrated. If these conditions cannot be met, it is useless to spend time calibrating the structure. These required conditions include:
   a. Good entrance conditions with a low velocity (Froude number less than 0.5).
   b. If the device to be calibrated is located right next to a supply canal (within 10 feet or so), the supply canal must have a fairly constant velocity.
   c. The staff gauge must be "zeroed."
   d. There must be no moss/algae buildup. That is, the conditions must not change with time.

4. The recommended calibration procedure for a non-standard site that meets the above conditions is as follows:
   a. A wide spread in the measured flow rate for calibration is required. At least a 2:1 ratio in the flow rates should be used to create the table.
   b. A **minimum of 10** values should be measured across the flow rate range.
   c. Data should be plotted on a graph. See **Figure 7** on the next page. Such a graph is a standard option in programs such as Microsoft Excel.
   d. The data should be plotted as a line. A program such as Microsoft Excel can be used to determine the calibration or the flow equation. For open channel devices, the equation should be of the form: $H = KQ^x$, where "x" is a value between 0.4 and 0.7.
   e. The regression coefficient (R^2) must be reported as well as the standard deviation. The USBR Water Measurement standard details the calculation for uncertainty. **Table 4** can be used as a guide to rate the quality of the calibration.

Figure 7. Plot of the calibration data

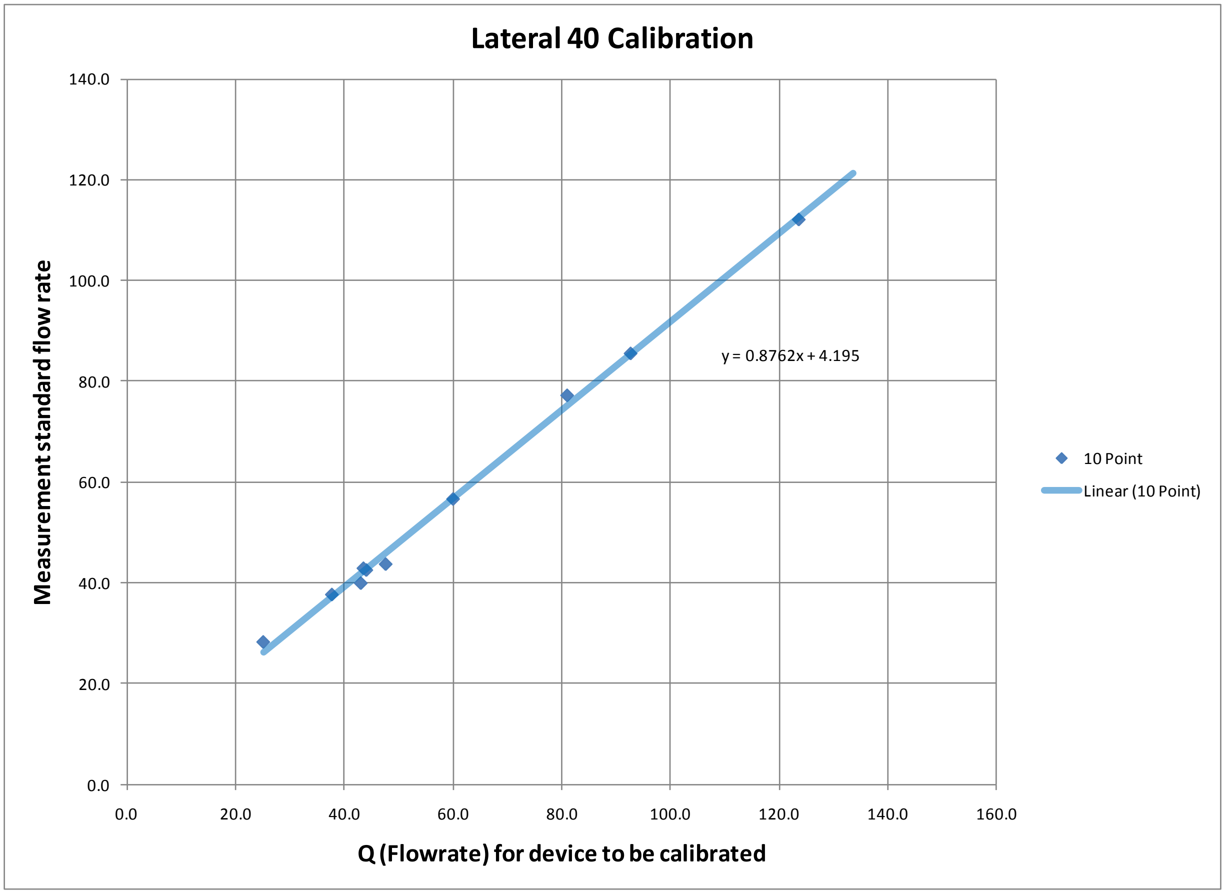


Table 4. Statistical evaluation of a calibrated site

Uncertainty Based on:
1 Standard Deviation

"Excellent" means ≤ 2%
"Good" means ≤ 5%
"Fair" means ≤ 8%
"Poor" means ≥ 8%

Verification of Errors in Volumetric Measurement

After a flow rate is measured and adjusted, turnout flow rates can vary with time due to changes in canal water level. The magnitude of the flow rate change will depend upon:

- The average change in water level across the turnout.
- The magnitude of the canal water level change.

The verification continues as follows:

1. Provide documentation of data obtained, and computations used, to verify the volumetric errors that occur due to the canal water level changes.
2. Compute the errors with the time-averaged change in canal water level at each of the 15 monitored turnouts.
3. Compute the error in volume using **Table 5**.

   The following is an example of how the table is used:

   > If the head loss across the turnout was 0.5' when the flow rate was set and measured, and the average water level during the delivery raised by 0.2', then the error in volume measurement was 14.4% – assuming a perfectly accurate flow measurement and no other cause of error. Because this exceeds the 6% allowable variation even with a perfect instantaneous flow measurement device, the cell for the 14.4% is shaded.

   Only those **<u>unshaded</u>** cells qualify for acceptable conditions – with a perfect instantaneous flow measurement device.

4. Include the following documentation for this time-related error, for each turnout:
   a. Both tabular and graphical data showing the recorded canal water levels during turnout deliveries, with a recording frequency. Clearly show the time(s) of flow measurement.
   b. A description of the turnout.
   c. The computations used to determine the average change in canal water level.
   d. The corresponding error (from **Table 5**) in volume measured.

Table 5. Evaluation of the impact of water level fluctuation

Average error in volume measurement, %								
Initial Head across the turnout, ft.	AVERAGE **rise** in the pool water level after the initial flow measurement, ft.							
	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
0.1	**32.0**	**44.3**	**55.2**	**65.1**	**74.1**	**82.5**	**90.4**	**97.8**
0.2	**17.6**	**25.1**	**32.0**	**38.3**	**44.3**	**49.9**	**55.2**	**60.2**
0.3	**12.2**	**17.6**	**22.7**	**27.4**	**32.0**	**36.2**	**40.3**	**44.3**
0.4	**9.3**	**13.6**	**17.6**	**21.4**	**25.1**	**28.6**	**32.0**	**35.2**
0.5	**7.6**	**11.1**	**14.4**	**17.6**	**20.7**	**23.6**	**26.5**	**29.3**
0.6	**6.4**	**9.3**	**12.2**	**14.9**	**17.6**	**20.2**	**22.7**	**25.1**
0.7	**5.5**	**8.1**	**10.6**	**13.0**	**15.3**	**17.6**	**19.8**	**22.0**
0.8	**4.8**	**7.1**	**9.3**	**11.5**	**13.6**	**15.6**	**17.6**	**19.5**
0.9	**4.3**	**6.4**	**8.4**	**10.3**	**12.2**	**14.0**	**15.8**	**17.6**
1	**3.9**	**5.7**	**7.6**	**9.3**	**11.1**	**12.8**	**14.4**	**16.0**
1.2	**3.3**	**4.8**	**6.4**	**7.9**	**9.3**	**10.8**	**12.2**	**13.6**
1.4	**2.8**	**4.2**	**5.5**	**6.8**	**8.1**	**9.3**	**10.6**	**11.8**
1.6	**2.5**	**3.6**	**4.8**	**6.0**	**7.1**	**8.2**	**9.3**	**10.4**
1.8	**2.2**	**3.3**	**4.3**	**5.3**	**6.4**	**7.4**	**8.4**	**9.3**
2	**2.0**	**2.9**	**3.9**	**4.8**	**5.7**	**6.7**	**7.6**	**8.5**
2.5	**1.6**	**2.4**	**3.1**	**3.9**	**4.6**	**5.4**	**6.1**	**6.8**
3	**1.3**	**2.0**	**2.6**	**3.3**	**3.9**	**4.5**	**5.1**	**5.7**

Average error in volume measurement, %								
Initial Head across the turnout, ft.	AVERAGE **drop** in the pool water level after the initial flow measurement, ft.							
	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
0.1	**100.0**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
0.2	**24.2**	**42.6**	**100.0**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
0.3	**15.0**	**24.2**	**35.6**	**51.2**	**100.0**	**n/a**	**n/a**	**n/a**
0.4	**10.9**	**17.1**	**24.2**	**32.5**	**42.6**	**56.5**	**100.0**	**n/a**
0.5	**8.5**	**13.3**	**18.5**	**24.2**	**30.7**	**38.2**	**47.5**	**60.2**
0.6	**7.0**	**10.9**	**15.0**	**19.4**	**24.2**	**29.5**	**35.6**	**42.6**
0.7	**6.0**	**9.2**	**12.6**	**16.2**	**20.1**	**24.2**	**28.7**	**33.8**
0.8	**5.2**	**8.0**	**10.9**	**13.9**	**17.1**	**20.6**	**24.2**	**28.2**
0.9	**4.6**	**7.0**	**9.6**	**12.2**	**15.0**	**17.9**	**21.0**	**24.2**
1	**4.1**	**6.3**	**8.5**	**10.9**	**13.3**	**15.8**	**18.5**	**21.3**
1.2	**3.4**	**5.2**	**7.0**	**8.9**	**10.9**	**12.9**	**15.0**	**17.1**
1.4	**2.9**	**4.4**	**6.0**	**7.6**	**9.2**	**10.9**	**12.6**	**14.4**
1.6	**2.5**	**3.9**	**5.2**	**6.6**	**8.0**	**9.4**	**10.9**	**12.4**
1.8	**2.3**	**3.4**	**4.6**	**5.8**	**7.0**	**8.3**	**9.6**	**10.9**
2	**2.0**	**3.1**	**4.1**	**5.2**	**6.3**	**7.4**	**8.5**	**9.7**
2.5	**1.6**	**2.4**	**3.3**	**4.1**	**5.0**	**5.9**	**6.7**	**7.6**
3	**1.3**	**2.0**	**2.7**	**3.4**	**4.1**	**4.8**	**5.6**	**6.3**

Combining Volumetric Measurement Error with Canal Water Level Fluctuation

Present the following information in a summary table for each turnout:

1. Turnout
2. Turnout design
3. Location of turnout (ID)
4. Previously computed flow measurement error, % (note: these are rarely more accurate than +/- 3%)
5. Computed volumetric error due to changes in canal level, %
6. Combined volumetric error. This last number is computed as follows:

$$\text{Combined \% error} = \sqrt{(\text{\% flow meas. error})^2 + (\text{\% volumetric error})^2}$$

For example, if the flow measurement error of a device is 4%, and the volumetric error caused by canal water level fluctuation is 4.5%, then:

$$\text{Combined error} = \sqrt{4^2 + 4.5^2} = 6.02\% = 6\%$$

For more information and support on measurement and calibration, please contact the Cal Poly Irrigation Training and Research Center at (805) 756-2434.

References:

Bureau of Reclamation Water Measurement Manual - 3rd Edition
Cal Poly Irrigation Training and Research Center - Flow Measurement (Fall 2011)